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SELF-DIRECTED MOVING STRATEGY FOR CLUSTER LEADERS TO MAXIMIZE THE LIFESPAN OF SENSOR NETWORK

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ABSTRACT:

In wireless sensor networks (WSNs), mobile elements (MEs) are a type of sensor node that can move within the network. These nodes are equipped with sensors and can move around the network to perform various tasks such as data gathering, routing, or energy replenishment. Mobile elements can be either pre-defined or self-organized. Pre-defined mobile elements are nodes that are programmed to follow a specific path or pattern of movement within the network. For example, in agriculture monitoring applications, mobile elements can be programmed to move along a specific path to collect data from various sensors that are spread across the field. Self-organized mobile elements, on the other hand, are nodes that can move in a more random and opportunistic manner. The research work proposes a new Self Organized trial onwards energy rich zones to minimize the energy hole formation.

Keywords: Wireless Sensor Network, Mobility, Cluster head, clustering, Self -Directed moving strategy, Network Lifetime

1 INTRODUCTION

A Wireless Sensor Network (WSN) is a network of autonomous devices called sensors that are used to monitor and collect data from the physical environment. These sensors are equipped with wireless communication capabilities, allowing them to transmit the collected data to a central processing unit for analysis. The sensors in a WSN can be deployed in various types of environments, such as forests, oceans, and urban areas, to monitor parameters such as temperature, humidity, pressure, vibration, and sound. These parameters are then used to make decisions and take actions based on the data collected. One of the key features of a WSN is its ability to operate in a decentralized manner, where the sensors work together to perform tasks without the need for a central control unit. This feature allows WSNs to be used in a variety of applications, including environmental monitoring, industrial automation, and healthcare. WSNs also present several technical challenges, including energy efficiency, data reliability, and security. These challenges have led to the development of various algorithms and protocols that optimize the performance of the network while ensuring data integrity and security.

In wireless sensor networks (WSNs), mobile elements (MEs) are a type of sensor node that can move within the network. These nodes are equipped with sensors and can move around the network to perform various tasks such as data gathering, routing, or energy replenishment. Mobile elements can be either pre-defined or self-organized. Pre-defined mobile elements are nodes that are programmed to follow a specific path or pattern of movement within the network. For example, in agriculture monitoring applications, mobile elements can be programmed to move along a specific path to collect data from various sensors that are spread across the field. Self-organized mobile elements, on the other hand, are nodes that can move in a more random and opportunistic manner. These nodes can move towards areas of high sensor activity or low energy, to perform tasks such as data collection, or to provide energy to other nodes. Mobile elements can improve the efficiency and effectiveness of wireless sensor networks in several ways. For example, they can be used to:

- Enhance network coverage: Mobile elements can move to areas where static nodes are not present or where signal quality is poor, improving the network coverage.
- Extend network lifetime: By providing energy to other nodes or performing energy-efficient routing, mobile elements can help extend the network lifetime.
- Improve data quality: Mobile elements can collect data from multiple sensors and average out the readings, providing a more accurate representation of the environment.
- Facilitate network maintenance: Mobile elements can be used to perform maintenance tasks, such as replacing dead batteries or repairing faulty nodes.

Mobile elements, such as mobile relays or mobile sinks, can significantly increase the lifetime of a wireless sensor network (WSN) by improving network coverage, reducing energy consumption, and enhancing data transmission efficiency. Here are a few ways in which mobile elements can contribute to the longevity of a WSN:
Increased coverage: Mobile elements can extend the network's coverage by reaching areas that are out of range of the stationary sensors. As a result, they can collect data from those remote areas and transmit it back to the base station. This reduces the number of hops required to send the data and, therefore, conserves energy.
Reduced energy consumption: The mobile elements can help the WSN conserve energy by reducing the number of sensor nodes required to transmit data. The nodes that are far from the base station can send their data to the mobile element, which in turn can forward the data to the base station. This reduces the energy consumption of the sensor nodes and extends their battery life.

Enhanced data transmission efficiency: Mobile elements can act as a relay or a sink for data transmission. They can use their mobility to move closer to the source of the data, and hence reduce the distance that the data needs to travel. This reduces the chances of packet loss, enhances the data transmission efficiency, and ultimately increases the lifetime of the WSN.
Overall, incorporating mobile elements into a WSN can significantly increase its lifetime by improving network coverage, reducing energy consumption, and enhancing data transmission efficiency. Mobile elements are an important component of wireless sensor networks, as they enable efficient data gathering, routing, and energy management, which are crucial for the successful operation of these networks Sensor nodes, are grouped together into clusters in order to avoid the aforementioned drawbacks, and each cluster is given a leader known as the cluster

head. It will typically be a sensor node with anenormous communication radius and abundant energy. Using an algorithm design technique, node clustering can be accomplished by having cluster members connect to the cluster head through a tree structure.

The wireless sensor network's lifespan is drastically decreased by the clusters' idle condition. The generation of energy holes in the network is thus avoided or delayed in research projects aimed at increasing the lifespan of wireless sensor networks. One of the better options is to alternate the single-hop sensor nodes (i.e., rather than overloading the same group of nodes, a whole different set of nodes will function as single-hop sensors). The best approach is to move the cluster head to a different place, which will also produce better results, or to change the cluster heads on a regular basis, which also involves replacing the single-hop sensors. So many studies have concentrated on the mobile cluster head, which shifts to an area rich in energy at the conclusion of each round. The following illustration shows the network's corona division and head cluster together.

2 Related Works

The energy hole issue has drawn attention in earlier studies because it is one of the key factors in reducing network lifetime. The focus of May's team was on implementing various techniques to reduce the occurrence of energy holes and thereby lengthen the lifespan of the network. To reduce the formation of energy holes, Work [7] employs the idea of numerous mobile sinks. The authors created a predetermined route for the sinks to travel by dividing the network into hexagonal tiles. In order to gather data, sinkholes halt at various points along a predetermined trajectory. Two stop time variations are shown in the text. Depending on the remaining energy in that stall zone, there are fixed time and variable stall times based on the LPP paradigm. The experimental results showed a very good improvement in network lifetime.

In work [8], the ILP model is used to determine the best locations after converting the base station location space to the final solution space. The authors used a geometric sequence to discretize the energy cost by splitting the disc into a limited number of sub regions and assigning a fictitious cost point to each sub region (FCP). While many earlier research studies concentrated on creating an integer linear programming model to execute on a continuous search space, the authors' new method allows ILP to be run on a finite space.

The mobile base station trajectory extraction procedure is the main topic of [3]. A mobile base station follows a course through the network, stopping at cluster beads to collect data packets. The cluster group can only make two hops, and the algorithm declares a set of energy-dense nodes as the cluster heads. Cluster heads gather and buffer data packets while clustering trees are built at the start of the data collecting round. When the base station approaches the cluster head, the cluster heads transmit the collected data packets to the base station. The algorithm is said to have a flaw in that it does not concentrate on the delay caused by the mobility of the base station.

A novel method for determining the number of hops was put out by the authors of [10]. When the network nodes are evenly spaced apart and the shortest path between the source and the destination is chosen, they take the number of hops into account. By using simulation, the analytical model is validated. The simulation results indicate a very good improvement in network performance over another conventional scheme. All research works to date have focused on improvising network lifetime and network performance by minimizing the energy consumption of each node.

The location of the cluster head is chosen as the rendezvous point for the base station, and the authors of [5] expanded their contribution with additional work mentioned in [Xing et al, 2008]. With the event-based data collecting approach suggested in [4], the base station only visits the cluster head when it creates data. Multiple movable wells travelling in a predefined direction are discussed in Work [6]. The sinks move around the hexagonal tiles that the creator divided the network into for data collecting. The dwell periods for sinks in the article are both constant and adaptive. To determine the best stopping time for the sinks, a new linear programming problem is created in adaptive stopping. Network simulation experiments revealed an improvement. In works [14,15], data collecting using a constrained number of hops is considered. Bounded relay hop mobile data collecting (BRH-MDG), which is described as an optimization issue, is a brand-new query-based mobile data collection strategy that was proposed by the authors of [15]. As polling sites, portions of sensor nodes were assigned to retain locally aggregated data and communicate it to the mobile base station when it approaches. Additionally, the authors promise that the sensor connected to the polling locations will have an efficient packet with a specific amount of hops. Another mathematical model was suggested by Chen et al. [15] in response to the BRH-MDG algorithm's flaw of failing to extensively assess and optimize the energy usage of the entire network. According to experimental findings, EEBRHM can extend networks' lifetimes by 730% when compared to BRH-MDG under conditions of restricted relay hop. The network's base stations. The ILP model is used to identify potential base station deployment sites. The authors also suggested a heuristic methodology to identify the ideal base station mounting site in addition to offering an ILP formulation for the installation of numerous base stations. The network longevity in simulation experiments has improved significantly. In [15] and [16], the segmentation of the scanned area into sub-areas is covered. For mobile sink-based wireless sensor networks, Chen et al. introduced the lifetime optimization technique bound by data transmission delay and hops (LOA DH).Several significant restrictions are examined, and an optimization model is suggested in LOA DH. The authors calculated the communication energy consumption using the maximum capacity routing technique, and a genetic algorithm is utilised to solve the optimization model, adapting the individuals to fit the requirements. The suggested method determines the best location and time to reside in order to extend the sensor network's lifetime. Experimental results prove that the proposed optimization model increases the lifetime of the network, the amount of nerves consumed between sensor nodes, and the amount of discarded data. For a mobile sink, the authors of [16] presented a delayed point (RP) bound path design. The network region is divided into multiple hexagons in the author's model, and RPs are placed at the geometric centre of each hexagonal sector. The reduction of RPs necessary to cover the complete network region is the aim of research effort. According to simulation study, the suggested algorithm significantly improves a number of performance parameters, including hop count, network lifetime, and many others, to demonstrate its efficacy.

The BR-CTR algorithm is the one suggested in [12]. (bounded relay Combination-TSP reduction). To reduce the number of transition points, the TSP-reduction restricted combination method travels to the convergence zone of sensor communication ranges. When the BR-CTR technique is paired with a path adjustment mechanism, the anticipated travel path can be effectively shortened even more. Comparing the proposed approach to existing single-hop and multi-hop mobile data collection algorithms, simulation results demonstrate its strong performance. The purpose of article [11] is to use tree structure and multi-hop concepts to shorten sensor node transmission distances. The suggested approach is a wise choice for designing a solid routing model for the sink based on the node's residual energy and also taking distance into consideration. The residual energy reserve is also boosted, balancing the network demand and increasing the life of the network. The suggested approach performs well according to experimental analysis, which also demonstrates proper performance in terms of network lifetime extension, transmission overhead, and throughput. In the event of a transmission delay, the suggested algorithm also permits message retransmission. The paper [Chang et al, 2016]'s major goal is to use the ideas of tree structure and multiple hops to shorten the transmission distances of sensor nodes. The location of the mobile sink, the separation between individual sensor nodes, and the residual energy of each sensor node are taken into consideration while deciding whether to build a routing structure. By lowering energy use and balancing network traffic, network lifetime can be increased. In terms of energy consumption, network lifetime, throughput, and transmission overhead, experimental findings clearly show that the proposed system performs significantly better than previous ones and has the capacity to deliver suitable performance.

By developing a new clustering method that produced a collection of dynamic clusters, [18] addresses the problem of extending network lifetime. The wireless sensor network's lifespan is increased because the power consumption is evenly distributed among all of the cluster heads. a flawed algorithm based on a study that computes cluster radius using a different directional approach. The authors increased the value of their work by advancing the On-demand, Optimal Clustering clustering technique (OPTIC). They refer to the earlier stated adaptive cluster head election process. The dynamics of the occurrences are the cause. The clustering approach, according to the authors, aims to reduce message and processing overhead. Simulation investigation reveals the proposed clustering model to be accurate. According to experimental findings, it outperforms other clustering algorithms in terms of network longevity and balanced energy parameter by more than 19%.

A novel genetic algorithm-based clustering technique with a newly defined objective function was put forth in [19]. The LEACH (steady-state phase) protocol in a heterogeneous environment is modified by the clustering algorithm suggested by the authors in these works. The number of cluster heads, compactness, and separation are three crucial parameters that the authors' new optimization model takes into account while determining the objective function. Experimental research demonstrates that the proposed optimization model is superior to the current optimization model in terms of lengthening network lifetime. For network clustering and cluster head selection, the authors of [20] address algorithms that use multi-attribute decision-making, adaptive fuzzy logic, and deterministic, probabilistic, and deterministic decision-making approaches. The authors note that while currently used techniques extend network longevity and energy efficiency, they do not improve service quality and security. To deliver a higher standard of service, the authors attempt to merge the ideas of computational intelligence with network intelligence. Both heterogeneous and homogeneous types of sensor networks exhibit a notable increase in network lifetime.

The research described in [21] suggests a brand-new phrase called SPDAC (shortest path detection for area coverage), which optimizes the network's transmission node's trajectory. By deploying sensor nodes using particular tactics, these actual nodes assist in resolving network coverage issues. By developing a novel schema prediction-based power consumption clustering protocol (PCP-EC) that reduces the overhead associated with static node communication, the authors also expand upon their previous work. According to the authors, the proposed models will give the maximization of network lifetime top priority. The effectiveness of the suggested algorithm in delivering higher quality of service is tested using a network simulator tool.

3 Issues with Predetermined Trajectory and Contributions of the Paper

Predetermined trajectories impose many drawbacks with regard to the lifetime of wireless sensor network.

- In case of predetermined trajectories, mobile cluster heads travel in the same roue repeatedly and stops at the same sojourn locations for data collection.
- After a specific number of rounds, one hop energy level at the sojourn points may fall below the threshold level, while the energy level at other areas away from the sojourn points may be better.
- Once the one hop energy level at the sojourn points falls below the threshold, it is not possible for the sensor nodes to communicate with the cluster heads.
- Also, the mobile cluster heads are programmed to stop at all sojourn points for a specific amount of time. Though, the one hop residual energy is below the threshold level, the mobile cluster head is not capable of taking an Self -Directed decision for not stopping at that point. Instead, it stops at the low energy point for data collection which makes the energy to drain below the threshold level thus minimizing the network lifetime.

Contributions of the Paper:

- A Self -Directed trail movement strategy for the mobile cluster heads to performs data collection.
- A data collection algorithm for cluster heads
- A new procedure for creating data collection trees using Algorithm for cluster tree formation for data collection and aggregation for cluster heads.
- A novel linear programming mathematical formulation to find the optimal sojourn duration for the cluster heads.

4. Representation of network and Research Problem Definition

4.1 Representation of network

The network model's underlying assumptions are as follows.

- The network type is a mobile cluster head and static sensor node heterogeneous network type.
- The network area is partitioned into grid sections, each measuring CR/2, where CR stands for the cluster heads' communication radius.
- The approximate number of cluster heads that should be placed in the network is N/(CR/2).
- To enable communication between each lattice's cluster heads and those of its neighbors, the radius of each lattice circle is taken to be CR/2.The cluster heads are assumed to have movement capacity.

- Data gathering and compilation are routinely carried out.
- A two-way, error-free data link is assumed to exist between the sensor nodes.
- An effective middle access layer that forbids data packet collisions and retransmissions
- High energy backup and a wide communication range are assumptions for cluster heads.
- Cluster heads can easily relocate from one rendezvous location to another.

4.2 Problem Definition

- A set of sensor nodes are densely deployed in an area with energy rich nodes as cluster heads and one mobile base station.
- The entire network is partitioned into grids with 'x' number of energy rich nodes, one node onside each grid and where x represents the total number of grids.
- Design a Self -Directed moving strategy for the base station to enable them to collect data from the sensor nodes.
- Devise a clustering protocol to enable the cluster heads to from cluster trees for the purpose of data collection.
- Design a linear programming optimization model for optimizing the stopping time of the base station at each rendezvous point.

5. Self -Directed Trial Strategy with Sector based Partitioning

5.1 Sector based Partitioning

Wireless Sensor Networks (WSNs) can be partitioned into different sectors based on various criteria such as geographic location, functionality, communication patterns, and energy consumption. The purpose of sector partitioning is to improve network efficiency, reliability, and scalability.

Here are some common ways to partition a WSN:

Geographical partitioning:

In this method, the WSN is divided into different regions based on the physical location of the nodes. The purpose of this partitioning is to limit the communication range of the nodes and reduce energy consumption. Geographical partitioning can also improve network coverage and reduce interference between nodes.

Functional partitioning:

This method involves dividing the network into different sectors based on the specific tasks or functions of the nodes. For example, some nodes may be responsible for sensing temperature, while others may be responsible for monitoring humidity or light intensity. Functional partitioning can help improve the efficiency of the network by assigning specific tasks to each node.

Communication pattern partitioning:

In this method, the network is divided into different sectors based on the communication patterns of the nodes. For example, nodes that communicate frequently with each other may be grouped together, while nodes that communicate less frequently may be grouped separately. This type of partitioning can help reduce network congestion and improve network efficiency.

Energy-aware partitioning:

This method involves dividing the network into different sectors based on the energy consumption of the nodes. The purpose of this partitioning is to ensure that the nodes with high energy consumption are separated from those with low energy consumption. This type of partitioning can help extend the lifetime of the network by reducing the energy consumption of the nodes.

Overall, sector partitioning is an important technique to improve the performance and efficiency of WSNs. The choice of partitioning method depends on the specific requirements of the network and the application. The proposed research work focus on partitioning the network based on geographical partitioning of networks. The network is partitioned in to approximately equal size sectors and each sector is deployed with a energy rich node destined as Cluster Head. The next task to form cluster groups inside each sector and form data collection trees using which the data is communicated from individual sensor nodes to cluster heads.This phase is dedicated to creating cluster groups in the network. The network is deployed with few energy rich nodes at each grid partition which acts as cluster heads. Each cluster head initiates a cluster initialization procedure for the purpose of forming clustering tree inside the grid. The clustering tree is used for the purpose of collecting residual energy and data from individual sensor nodes. At the onset of first data collection round, the mobile base station will position itself in any of the grid for data collection. The cluster head of the specific grid initiates data collection by calling the clustering procedure and initiates data collection. At the end of the data collection round, the aggregated data is communicated to the base station by the cluster head.

In case of subsequent rounds all the cluster heads initiate the cluster initialization procedure and from data collection trees. Using the data collection trees, the residual energy of the individual sensor nodes are collected and the average energy of the grid is calculated by the cluster head. The base station decides the next stop to sojourn based on the energy reserve inside each grid. It chooses the grid with maximum reserve to sojourn,

Any ties in the selection of the leading sensors will be randomly broken during the cluster initialization process by the algorithm itself. The cluster heads or leaders as well as the clustering trees will be initialized at the conclusion of Phase I. In Phase II, these clusters will be used to select an appropriate area for the base station to live. Each sensor in the network initializes its my leader id to NULL and MYHOPCOUNT to at the start of the CLUSTER INITIALIZATION procedure. Each leading sensor then transmits to its neighbors a (MYID, HOPCOUNT =1) message. After getting the message, neighbors compare HOPCOUNT and **MYHOPCOUNT**

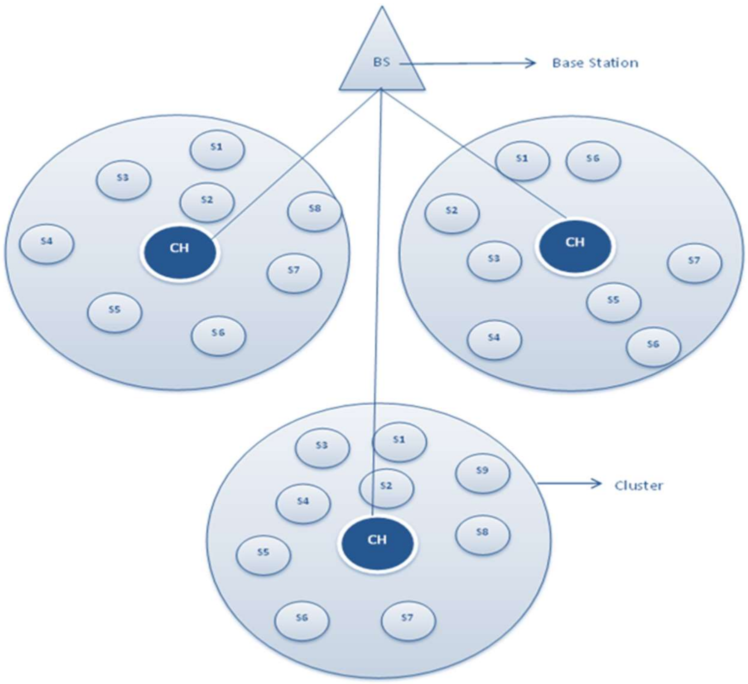

Figure1. Cluster formation across the network after Phase I

Algorithm for CLUSTER INITIALIZATION
Input: Flat Sensor Network
Output: A set of Clusters with Leaders
1. CLUSTER INITIALIZATION ()
2. Each sensor sets MYLEADERID = NULL and MYHOPCOUNT = ∞
3. Each Leader Sensor broadcast a (MYID, HOPCOUNT =1) message to its first corona sensors.
4. Each first corona sensor after receiving the message
5. If (HOPCOUNT < MYHOPCOUNT) then
6. MYLEADERID = MYID; **7.** MYHOPCOUNT = HOPCOUNT.
8. NEXT_HOP = Sensor from which the message was received
9. HOPCOUNT = HOPCOUNT + 1
10. Broadcast the message (MYLEADERID, HOPCOUNT) to the next Corona sensors.
11. Else
12. Sensors ignore the message
13. Endif
14. End

Then, a similar message is communicated to its instant neighbors by incrementing

HOPCOUNT by one. Similarly, each sensor may be able to receive multiple messages from multiple lead sensors. But they chose the leader who had the least number of jumps compared to the others. At the end of this procedure, each sensor connects to any of its nearest boot sensors . These cluster groups will be used in Phase II to decide on a suitable location for the base station to reside

5.2 Phase II – Deciding Sojourn Location

Choosing the base station's halting point is the next step. Each cluster leader starts the cluster initialization process and gathers data from the trees to complete this task. The cluster leader determines the average energy of the grid by calculating the residual energy of each individual sensor node using the data collecting trees. On the basis of the energy reserve within each grid, the base station chooses the next location to sojourn. It chooses to travel on the grid with the most reserve. The base station broadcasts a message (MYLOC, SEND ENERGY) to all cluster leaders in order to choose the next point. The lead sensors build clustering trees after receiving the message by using the clustering technique outlined in the preceding section. Leading sensors continue to maintain Clustering trees for the duration of the network. It is not necessary to constantly reconstruct trees. Each lead sensor will send a SEND RESIDUAL ENERGY request to every other sensor in the cluster when it has been created. The NEXT HOP path created during the CLUSTER INITIALIZATION procedure is used by the master sensor to forward the message to its members. Cluster members transmit their respective leaders the requested residual energy after getting the request message from them. The leader sensors summate the energy level after receiving the energy value from their cluster members and determine the average residual energy that is present there.

Algorithm for Base station Placement
1. Base station transmit (MYLOC, SEND_ENERGY) to the Leader Sensors
2. CLUSTER INITIALIZATION ()
3. Each Leader Sensor transmits SEND_RESIDUAL ENERGY to its cluster members.
4. Each Sensor broadcast the residual energy to its leader
5. Leader consolidates the residual energy to calculate the average energy in its zone.
6. The average energy is sent to the base station.
7. After receiving the message the base station compares the highest residual energy zone with its current location's energy
8. It moves to the new zone if it is higher than its current location
9. Else stay in its current position for another time period T.

Using the MYLOC value, the computed energy is transmitted to the base station. Base station chooses the next location for its journey based on the information it has acquired from the leaders. It selects the region with the most remaining energy. The entire network lifetime can be calculated as the sum of the base station's halting periods at various locations "until any one sensor node dies of energy depletion." Alternatively, we define it as "Until a specific percentage of sensors perish." Both definitions are taken into account when performing simulations. The results of the experiment reveal a significant improvement in lifespan of the network and energy consumption compared to the traditional static sink situation.

5.3 Performance Analysis

To determine the time complexity of the heuristic technique, performance analysis is conducted. Assume there are 'n' sensors in the sensing field to calculate the algorithm's time efficiency. Since there are only 'k' cluster heads in phase I, each sensor will almost k times complete the comparison process. The time complexity of the phase I algorithm is O(nk) since the comparison count for this phase is nk .

In phase II, each leader sensor sent a send of residual energy to the cluster members. Each sensor responds by transmitting its remaining energy. The cluster's other members provide energy to all of the leader sensors at that point. Each leader sensor initially transmitted a send leftover energy to its cluster members in phase II. Each sensor transmits its remaining energy in response. All of the leader sensors then get energy from every other member of the cluster. Neglecting the constant numbers, it is possible that n+k transmissions and receptions occurred on average. Phase II's time complexity is reportedly O (n+k).

6 Linear Programming Formulation to Optimize Sink Sojourn time

The work's contribution is further expanded by the mathematical formulation we provide, with the goal of giving the cluster head an efficient stopping time. The remaining energy of the rendezvous zone is not taken into account by the stopping time period "t" stated in the preceding section. Instead, it comes to a standstill for a set amount of time regardless of the amount of remaining energy present at the specific sojourn place. In this part, we attempt to make the cluster head's rendezvous time as flexible as possible while taking the balance of energy present at the sojourn location into account. The sojourn time of the cluster head is optimized using a linear programming model depending on the remaining energy of the one-hop sensors.

Enhancing the lifetime of a Wireless Sensor Network (WSN) by optimizing the sink's sojourn time using a Linear Programming (LP) formulation can be an efficient approach. Here are some factors that contribute to its efficiency:

- Mathematical Optimality: LP models provide mathematically optimal solutions within the given constraints. The optimization problem is formulated as a linear objective function, which can be solved using efficient algorithms. This ensures that the obtained solution minimizes the sojourn time of the sink, thereby reducing energy consumption and extending the network lifetime.
- Energy Efficiency: By minimizing the sink's active time, the LP formulation focuses on reducing energy consumption. This can significantly enhance the lifetime of the WSN, as energy conservation is critical in resource-constrained environments. By optimizing the sojourn time of the sink, the LP formulation directly addresses the energy efficiency aspect of the network.
- Flexible Constraints: LP formulations allow for flexible inclusion of constraints. You

can incorporate various factors such as maximum allowable sojourn time, data transmission requirements, and energy limitations of the sensor nodes. This flexibility allows you to tailor the formulation to the specific requirements and constraints of the WSN, improving the efficiency of the optimization process.

- Scalability: LP models can handle large-scale WSNs efficiently. Linear programming algorithms have been extensively studied and optimized, enabling them to handle problems with a large number of variables and constraints. This scalability makes the LP formulation suitable for real-world WSN deployments with a significant number of sensor nodes.
- Integration with Existing Tools: LP formulations can be easily integrated into existing optimization frameworks and solvers. There are robust software packages and libraries available that can efficiently solve LP problems. This integration simplifies the implementation and enhances the efficiency of the optimization process.

However, it's important to note that the efficiency of the LP formulation also depends on the size and complexity of the WSN, the accuracy of input data, and the computational resources available. Large-scale WSNs with complex network topologies and dynamic environments may require advanced optimization techniques or heuristics to handle the problem efficiently.
Overall, utilizing a Linear Programming formulation to optimize the sink's sojourn time can be an efficient approach for enhancing the lifetime of a WSN by reducing energy consumption. It offers mathematical optimality, flexibility, and scalability while addressing the key objective of energy efficiency.

6.1 Mathematical Formulation: Variables and Parameters

To increase the sensor network lifetime by optimizing the sink's sojourn time while considering the residual energy of one-hop sensor nodes, you can formulate the problem as a Linear Programming (LP) model. The objective is to find an optimal scheduling strategy for the sink to minimize its active time while considering the energy constraints of the sensor nodes. Here's a formulation outline:

Parameters:

- Let N be the set of sensor nodes.
- Let E(n) be the residual energy of sensor node n.
- Let d(n) be the data generated by sensor node n.
- Let T(n) be the maximum allowable sojourn time for the sink at sensor node n.
- Let x(n) be a non-negative variable indicating the sojourn time of the sink at sensor node n.

Decision Variables:

- Let y be a non-negative variable indicating the overall sojourn time of the sink.

Objective Function:

- Maximize the sensor network lifetime by minimizing the overall sojourn time of the **sink:**

maximize y

Constraints:

- The overall sojourn time of the sink should be less than or equal to the maximum allowable sojourn time at any sensor node:
- $y \leq \min(T(n))$, for all n in N

- The overall sojourn time of the sink should not exceed the residual energy of any active sensor node:
- $y \leq \min(E(n))$, for all n in N
- The sum of the data transmitted by all active sensor nodes should not exceed the overall sojourn time of the sink:
- $\Sigma(x(n) * d(n)) \leq y$, for all n in N

Non-Negative Constraints:

- $y, x(n) \geq 0$, for all n in N

This formulation represents an LP problem where the objective is to maximize the sensor network lifetime by minimizing the overall sojourn time of the sink (y) subject to various constraints. By solving this LP model, an optimal scheduling strategy can be obtained that considers the residual energy of the one-hop sensor nodes. The objective is to minimize the overall sojourn time of the sink while ensuring that the energy constraint is satisfied for each sensor node, thereby increasing the network lifetime.

Simulation Results

To show the effectiveness of the suggested algorithm, simulation experiments are run using a network simulator tool. We experiment with both the scenarios where the cluster heads stay for a predetermined amount of time and the optimal dwell duration given by the linear programming formulation. Here is how the simulation is set up.

- The network has 200 nodes, and the sensor nodes are dispersed randomly over the sensing area.
- For the simulation, a first-order radio model is taken into account.
- The first-order radio model takes into account the following parametric parameters to broadcast a k-bit message across a distance d.
- The path loss exponent and the energy required to transmit one bit are represented by and eamp, respectively.

200 sensor node sensors and cluster heads are randomly deployed to begin the simulation. As mentioned in the first section of our study, a cluster head is initially assigned to gather data for a specified dwell period. The cluster head's movement is taken into account while using the suggested trajectory. For a predetermined number of rounds, data gathering is conducted. It is investigated how long the network will last in terms of rounds. Here, network lifespan is defined in two different ways.

- The cluster head can do one round until the remaining energy of one hop at any dwelling reaches the minimum energy requirement.
- Second, how many rounds the cluster head can support until the remaining energy of one hop of "x" number of households falls below the minimal energy need.

Both the proposed research work and the mathematical formulation model are put through simulation tests. The number of iterations the cluster head can undergo with the state before one residence's leftover energy reaches the minimum energy is investigated. The outcomes are displayed in Figure 3. Here, four various strategies are examined.

1. Cluster head is situated at the network's geometric centre
2. A mobile cluster head situated at the network's edge
3. A portable cluster head positioned at sporadic areas with abundant energy
4. Self -Directed trail movement strategy

In terms of laps, the proposed work represents a major improvement. Investigated in a similar manner is the network lifetime that the cluster head can sustain before the remaining energy of the 5% of dwellings drops below the minimum energy need. Figure 3 displays the final result. Again, the Self -Directed moving technique outperforms the competition in this instance. Investigated in a similar manner is the network lifetime that the cluster head can sustain before the remaining energy of the 10% of dwellings drops below the minimum energy need. The outcome is displayed in Figure4.

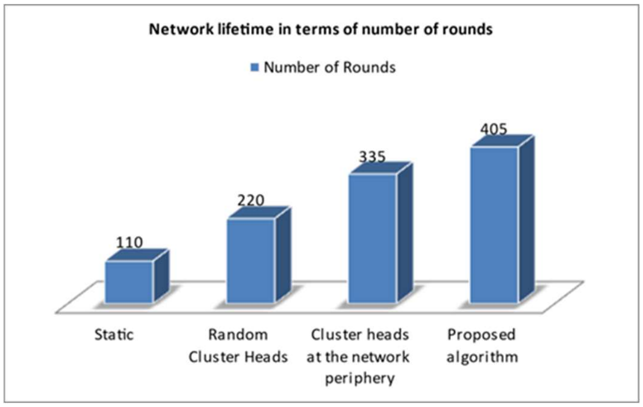

Figure 2 Network Lifetime (Until one node dies)

For all four methodologies, the average number of live nodes in the network after several iterations of data collecting is also studied. In comparison to existing methods, the proposed models feature more active nodes, which would directly affect the network longevity.
The least amount of active nodes are present in the other three models, which suggests a shorter network lifetime. In Figure 5, the number of dead nodes is also counted in the same way, with the proposed trajectory model having the fewest dead nodes when compared to other models. The outcomes are displayed in Figure 6.

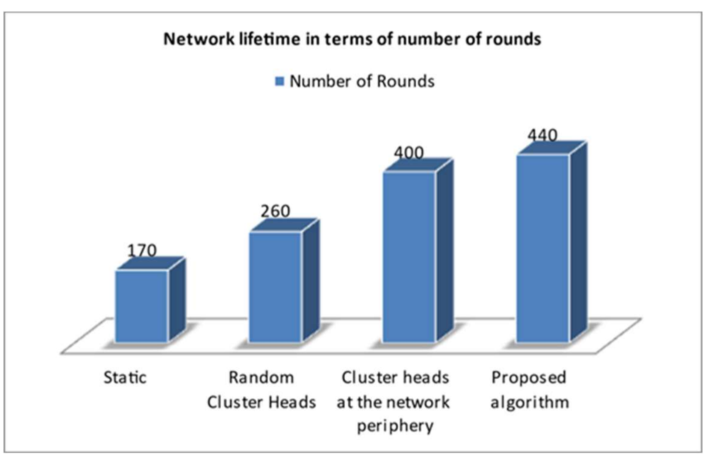

Figure 3 Network Lifetime (Until 5% of sensor nodes dies)

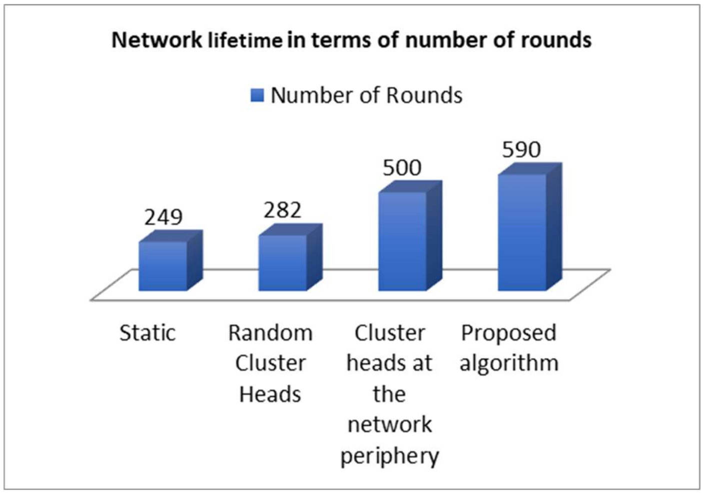

Figure 4 Network Lifetime (Until 10% of sensor nodes dies)

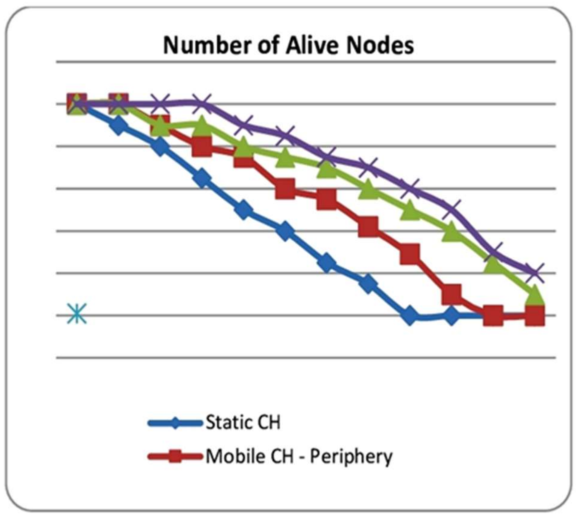

Figure 5 Number of alive nodes after specific number of rounds

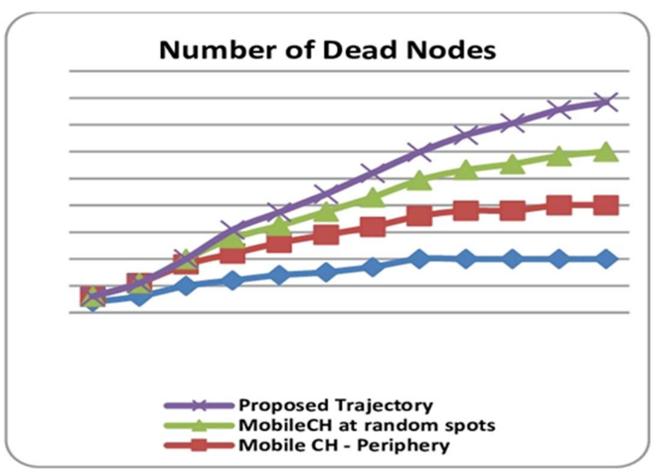

Figure 6 Number of dead nodes after specific number of rounds

8 Conclusions and Future Work

A unique Self -Directed moving technique for mobile cluster heads toward energy-rich zones is offered in the research. By distributing the load among all sensor nodes, mobility has shown to be particularly effective in lowering the formation of energy holes. The research suggests anSelf -Directed moving technique for data collecting using mobile cluster heads.Rather than moving the mobile cluster heads on a predetermined trajectory which may not be energy conscious, anSelf -Directed moving strategy is proposed to enhance the network longevity. Also, predetermined trajectories demand the cluster heads to repetitively stop at the same sojourn points which results in formation of hotspot. As a consequence of this, the network lifetime is declined this may yield a poor network performance. The proposed self -Directed moving strategy exhibits a good performance in comparison with the other models which involves mobile elements moving along a predetermined pathway.

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